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Abstract: Intellectual Property Rights (IPRs) are a key driver of economic growth as they provide agents with incentives to invest in Research and Development (R&D). The importance of IPRs should however vary when one moves along the technological frontier as firms can rely upon other mechanisms (i.e. imitation, equipment) to bring new products to the market place. An emerging strand of literature indeed has stressed how the incentives to growth vary according to the position of economic agents along the technological frontier. In this paper we explore variations at the intersection of these two factors – strength of IPRs and distance from the technological frontier - and show how IPRs relate to incentives for innovation at various stages of the latter. Using firm-level survey data for a sample of firms from a group of transition economies over the period 2002 to 2009, we provide evidence of heterogeneity in firms' decision to invest in R&D to increasing strength in IPRs as we depart from the technological frontier. Specifically, we show that *laggard* firms in countries with stronger IPRs are more likely to invest in R&D than similar firms in countries with weaker IPRs. The effect is mainly driven by firms in sectors which make intensive use of legal mechanisms to appropriate R&D. Finally, the effect matters the most for firms introducing incremental innovations such as upgraded products, young and small firms. The results suggest that IPRs lead *laggard* players to invest in own R&D, possibly by limiting the ability of firms to absorb external knowledge.

Keywords: IPR protection; Technological frontier; Innovation; R&D; Transition economies.
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1. Introduction

The ability of a country to grow and prosper rests ultimately on the efforts of private agents towards increased efficiency, e.g. the introduction of better production processes and new products/services. Expenditures in Research and Development (R&D), the most typical input of these activities, contribute to the prosperity of countries also by spilling over other economic agents: in fact, despite providing agents and countries with better opportunities, the outcomes of R&D are only partially appropriable (Romer, 1986).

A strand of literature in growth economics has stressed how the drivers of growth differ along the technological frontier (Acemoglu et al., 2006). Accordingly, investments in R&D and the availability of skilled personnel are more important for growth as one approaches the technological frontier, whereas imitation (i.e., adoption of existing technologies) is more relevant as one departs from it.

The main purpose of this paper is to highlight the heterogeneous impact of a functioning Intellectual Property Rights (IPRs) system on the likelihood of firms to engage in R&D at different stages of a country's development and in different industrial settings. We focus on Eastern European transition countries, which have started to strengthen their IPRs systems only after the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) came into force in 1994 and are still technologically laggard with respect to Western industrialized countries. Convergence towards a Western-type IPRs system can be seen for such transition countries as a sort of unexpected shift from an approach largely favorable to allow imitation and even stealing of new technologies to an approach aimed at guaranteeing legal security for intellectual property rights.

We expect that the likelihood of firms to engage in formal R&D activities varies not only across countries – i.e. according to the degree of IPRs enforcement – but also along the industry's technological frontier – i.e. according to the (relative) technological competitiveness of the firm. As argued by Lall (2003) countries at different levels of industrial and technological development face very different economic costs and benefits from stronger IPRs. Within a North-South general equilibrium product cycle framework, Helpman (1993) shows that stronger IPR protection leads Northern countries to expand the variety of differentiated products whereas it determines a reduction of the rate of imitation by Southern countries.

Moreover, exploring variations at the intersection of these two factors could uncover interesting nuances in how IPRs relate to incentives for innovation at various stages of development. Firms are heterogeneous not only in terms of size but also in terms of technological capabilities, and this may lead to differences in their innovation behaviors and performance (Dosi, 1988; Cohen, 2010). Thus, given that innovative activities tend to be accumulated from learning, exhibited in tacit and firm-specific knowledge, and embodied in organizational routines, one may argue that countries with weaker IPRs systems can substitute internal R&D with spillovers from outside patents, whereas these spillovers might be less accessible in countries with stronger IPRs systems when they are legitimately protected by the originating parties. This effect might be more pronounced when one departs from the technological frontier – where the gains from imitation are exhausted – and when externalities arising from imitative efforts are more relevant.

Using 5 waves of the EBRD/World Bank Business Environment and Enterprise Performance Survey (BEEPS), a database covering firms in transition economies, we analyze over the period between 2002 and 2009 whether differences in the functioning of the IPRs systems – measured in terms of various dimensions, including *de facto* enforcement and *de jure* patent and copyright protection – affect the propensity to engage in R&D activities. The empirical investigation, conducted in relation to the impact of IPRs systems along the technological frontier, indicates that firms are more likely to invest in R&D in countries with stronger IPRs systems and that the relationship between R&D and technological frontier is, as expected, positive. Interestingly, we show that this relationship varies according to the strength of the IP system. Whereas firms at the technological frontier are as likely to invest in R&D, irrespective of the level of IPRs in place, laggard firms, that is those firms which stand far from the technological frontier, are more likely to invest in R&D when IPRs are properly protected and enforced. Furthermore, this effect is mostly driven by those sectors which rely the most on IPRs as their preferred appropriation strategy.

The paper is organized as follows. Section 2 reviews the relevant theoretical and empirical literature on the relationship between strength of IPRs and undertaking of innovative activities. Section 3 introduces empirical model, data, and econometric strategy. Section 4 discusses the main results, whereas Section 5 draws some concluding remarks.

2. Literature review

Over the last two decades a number of countries started to strengthen their laws in the area of IPRs, following the successful conclusion of the TRIPs Agreement (Maskus, 2000; Branstetter et al., 2011). In fact, the strength of IPRs is a key driver of economic performance in R&D based growth models (Aghion and Howitt, 1992; Eicher and Newiak, 2013; Kim et al., 2012).

From an economic standpoint, IPRs carry a tension between opportunity and appropriability (Arrow, 1962; Nordhaus, 1969). Strengthening IPRs regimes enable firms to internalize part of the spillovers that stem from R&D activities, and hence provide incentives to engage in R&D even more intensively (Samariego, 2012). Similarly, stronger IPRs limit the ability of agents to access to knowledge spillovers – i.e. through imitating competitors' products – and could potentially lead to wasteful R&D duplication (Murray and Stern, 2007). Conversely, stronger IPRs should induce firms to disclose the outcome of their R&D activities, and hence increase the pool of knowledge available for third parties to build upon.

Dialectic considerations of the rights innovators can have over their innovations gained a role in the economic analysis of technological change at least since the pioneering works by Barzel (1989) and especially North (1990), challenging the standard view that the evolution of property rights leads straightforwardly toward increased economic efficiency. These authors have created room for abandoning the assumption that a monotonic relationship exists between strength of IPRs and innovation. In fact, drawing on the general principles and statements sketched above, the subsequent literature has highlighted advantages and disadvantages of IPRs. Among the pros, Encoaua et al. (2006) identify the following: i) by granting exclusionary rights to inventors, the government delegates the R&D decision and the responsibility of recovering her R&D investment in the hands of the inventor; ii) it is implicit in the presence of a (strong) IPR protection system the assignment of innovation costs to users rather than to tax payers; iii) in implementing an IPR system the government does not need to require typically private information about R&D cost and private value of the invention; iv) the information disclosure requirement of patents favors the diffusion of knowledge. Among the cons, Arora et al. (2008) mention: a) the fact that the costs of disclosure can more than offset the private gains from IPR protection; b) the likelihood that profit maximizing licensing decisions of upstream inventors may retard downstream innovation; c) the possibility that firms recur to IPRs to block competitors from using their innovations in subsequent research, thereby dampening the pace of advance; d) the emergence of "thickets" where transactions costs can impede innovation in those complex products for which firms possess strong and diversified rights.

In this vein, the alternative hypothesis that only above a certain minimal level does protection of IPRs result in more sustained innovation and long term economic growth has gained consensus in the recent years within the field of both theoretical and empirical investigation (Bessen and Maskin, 2009; Furukawa, 2010; Gangopadhyay and Mondal, 2012). In addition, Furukawa (2010) and other authors (including Murray and Stern, 2007; and Lerner, 2009) found evidence of an inverted U-shaped relationship between strengthening of IPRs protection and innovation activities. Enhancing IPRs protection thus reduces innovation activities when IPRs protection is already strong. On the one side, this suggests that there should be an optimal level of IPRs protection which maximizes the innovative effort put forward by firms and results in accelerated economic growth. However, on the other side it seems likely that below and above such threshold the incentive to innovate and the efficiency of the overall innovation system becomes smaller, with institutional factors playing a role in determining the inverted U-shaped relationship emerged from empirical studies.[1]

The concept of technological frontier has to be understood as "the highest level reached upon a technological path with respect to the relevant technological and economic dimensions" (Dosi, 1982; 9. 154). Accordingly, investments in R&D and the availability of skilled personnel are more important for growth as economic agents approach the technological frontier, whereas imitation (i.e., adoption of existing technologies) is more relevant as one departs from it. By following Acemoglu et al. (2006), one may assume that, according to their stage of development, countries are likely to choose either an investment-based or an innovation-based strategy, with the former relying on existing firms and sacrificing selection of firms and managers, and the latter limiting investment but supporting rigorous selection of both firms and managers. Within

[1] For example, implementation of the national treatment principle prescribed by international agreements, entailing equally strong protection for both domestic and foreign innovations, might be incomplete or deliberately pursue the strategy of advance domestic technology adoption from abroad (Kumar, 2003; Lorenczik and Newiak, 2012). From such a perspective, existence of a non-linear relationship between strength of IPR protection and innovation suggests that enforcement of the national treatment may produce negative results in terms of domestic firms engagement in innovative activities (Lorenczik and Newiak, 2012).

this framework, countries relatively backward in terms of both innovativeness and prevailing institutional arrangements may tend to abandon too early the investment-based strategy, therefore facing possible losses. In turn, more advanced countries already pursuing an innovation-based strategy would take additional advantage from strengthening the institutional setting supporting the pursuit of innovative activities. Accordingly, countries may remain trapped with “inappropriate institutions” and obsolete technologies whenever they prove unable to design IPRs systems and other institutional arrangements in a way that allows them to extract the greatest benefits in consideration of their distance to the technological frontier.

Similarly, firms’ competitive strategies are expected to vary according to their level of efficiency. Firms standing in proximity of the technological frontier are more likely to pursue an innovation-based strategy, focused on the generation of own knowledge. On the one hand, competition at the technological frontier tends to be harsher and based on other determinants than price; it hence requires firms to take actions to maintain their lead (Reinstaller and Unterlass, 2012). As gains from imitation or absorption of outside knowledge (i.e. through reverse engineering or adoption of external technologies via new equipment) will be limited, firms will have to strive for own creation of knowledge. R&D investments are the most salient strategy to the purpose. On the other hand, R&D investments are characterized by high sunk costs and little reversibility, high uncertainty and partial appropriability. Intellectual Property (IP) protection hence is sought for entrepreneurs to engage in R&D investments. Comparing the relative merits of strong and weak IPRs and taking into account the role of R&D spillovers, Denicolò and Franzoni (2012) support this view by showing that competitive innovation characterized by high R&D costs calls for strong IPRs and noncompetitive innovation for weak IPRs.

Far from the frontier, however, strong IP protection might also prevent firms from gaining access to external knowledge. By considering two dimensions of the patent right, its length and its breadth, Gallini (1992) claims that increasing patent breadth can be considered as the main driver of increasing imitation costs. Therefore, firms will have to develop endogenous capabilities through R&D in order to be able to introduce innovations.

Micro-level studies on how IPRs affect incentives to innovation along the technological frontier are quite recent. Kim et al. (2012) study the changing role of patents at different degrees of development. The authors present two sets of analyses, one for countries and one for a set of Korean firms, and show that patent protection is a significant determinant of growth in developed countries whereas utility models, supposedly weaker than patents, are more relevant in developing economies. Firm-level evidence supports the view that laggard firms rely more upon utility models, and that substitute the latter with patents when they develop more advanced capabilities. Adaptive or imitative innovations are thus typical of economic agents with low absorptive capacities and serve as "learning device" to switch to an innovation-based growth strategy, required to stay competitive as we approach the technological frontier. Consistent with this view, using firm-level data from the Community Innovation Survey (CIS) for 18 European countries, Hölzl and Janger (2013) find that the availability of skilled labor, innovation partners and technological knowledge result in lower innovation barriers for firms located in countries close to the technological frontier. Besides, these authors show that as the distance to the technological frontier widens the share of innovators decreases, whereas that of firms not interested or in no need of innovation increases.

3. Model, Data, and Variables

For the purpose of the present study we use the European Bank for Reconstruction and Development EBRD/World Bank Business Environment and Enterprise Performance Survey (BEEPS), a database covering firms in transition economies. We use the 5 waves of BEEPS – 2002, 2005, 2007, 2008, 2009 – which mostly differ in the spatial coverage. The surveys cover 25950 firms surveyed 29716 times. 3392 firms have been surveyed twice, whereas 374 firms three times. Although the BEEPS was specifically designed to assess the extent to which government policies and practices facilitate or impede business activity, it provides an interesting array of information on the behavior and performance of firms, including sales, employment, investments in R&D, the introduction of new products and the refinement of existing ones.[2] Our main variable of interest is whether firms engage in formal R&D activities (RD). We use question in the BEEPS survey which explicitly refers to R&D investments to generate a dummy

[2] Details on the construction of the survey can be found on the homepage of the EBRD under "http://www.ebrd.com/pages/research/economics/data/beeps.shtml". Lee and Weng (2013) provide a short yet exhaustive description of the survey process.

which takes on value 1 when firms respond positively to this question. Of the 4749 firms for which we have information, 1865 (39,3%) indicate that they had invested in R&D.

The concept of distance to the frontier is often associated to countries and sectors and either based on ex-ante distinctions between developed and developing countries (Park, 2008) or measured in terms of an income-based evaluation of the level of development, e.g. Real GDP per capita or relative labour productivity (Hòlzl and Janger, 2013). In this work we follow the second approach and employ a continuous measure of distance-to-frontier such as labor productivity (sales per employee) relative to what we define as technological frontier: the labor productivity of the respective ISIC Rev3 Industry in the USA in the focal year.[3] We employ exchange rates from local currencies to USD and GDP deflators taken from the data section of the website of the IMF since information from the BEEPS is expressed in local currency units.[4] We chose labor productivity because it is a reliable measure of the competitiveness of an economy. We chose the USA as we expect that the most efficient productive technologies are employed in what is considered the most competitive market around the world. We measured the technological frontier as the 5 year moving average labor productivity of the 2-digit NACE reference sector in the US, extracted from the Structural Analysis (STAN) database provided by the OECD. Closeness to the frontier is measured as the ratio of labor productivity relative to that of the frontier. The average productivity of the sampled firms is almost 1/8 of the average productivity in the US in the focal sector. As some firms (172 or 3.6%) happen to be above the frontier, we artificially transform this ratio to 1 so that the firms are considered to be at the frontier.

IPRs scores or indexes may prove useful when facing the issue of how stronger IPRs systems enhance innovativeness, or when trying to detect whether innovative countries display a higher attitude towards evolving the institutions associates with stronger IPRs. We measure IPRs with the International Property Rights Index (IPRI) proposed by the Property Rights Alliance, in particular the section related to IPRs. IPRI is based on a

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[3] Labor productivity in the sampled countries is expressed in real terms and has been transformed in US dollars from local currency units. We firstly deflated sales figures by the country-year specific GDP deflators. We then used the average of the monthly averages of exchange rates in the focal year to transform the real values in US terms.

[4] Industry specific deflators are not available for most of the countries in this study, so we have to rely on the broader GDP deflator. Exchange rates are for the year of the interview, calculated as the average of monthly averages. The only exception is Uzbekistan, for which information about exchange rates was not reported and was extracted manually from specialized websites and calculated as the average of the last day of the months in the focal year.

multitude of sources of information encompassing a battery of dimensions of the IPR system such as enforcement and patent and copyright protection; for the purposes of our analysis we use the release of the 2008 IPRI. Specifically, the Index is based on 1) national experts' opinions on the actual functioning of the intellectual property system and its enforcement; 2) objective criteria such as coverage, membership in international treaties, restrictions on patent rights, enforcement, and duration of protection as in Ginarte-Park Index of Patent Rights (Ginarte and Park, 1997, Park, 2008). 3) the Office of the United States Trade Representative "Special 301" watch list, reflecting piracy rates in the business software, entertainment software, motion picture, record and music industries.[5] It is hence a measure that combines *de jure* and *de facto* measures of IPRs' strength. Another advantage of the Index is the geographical coverage, rather limited for commonly used measures – i.e. Ginarte and Park (1997) and Park (2008). The index ranges between 10, the highest value, and 0. Finland scores the highest value on the ranking for IPR protection, 8.6. Most developed countries vary in the extent to which copyright is effectively protected whereas patent rights and their enforcement are quite homogeneous. Transition economies, the focus of this study, vary along all three dimensions.

Finally, we use information about the use of a variety of mechanisms to appropriate the returns from innovation from the Carnegie Mellon Survey as in Cohen et al. (2000) and adapted to 2-digit NACE sectors in the manufacturing macro-sector.[6]

Table 1 lists the countries included in the sample and the distribution of firms which reported whether they perform R&D. It shows that there is substantial variation in terms of *de facto* and *de jure* IP protection across the sample reported in the final column. Countries like Belarus, Kyrgyz, Tajikistan and Uzbekistan do not provide any legal protection for intellectual property, whereas most of the countries which have adhered to the EU have modern IP-related legal infrastructures. Such high dispersion provides a particularly rich sample, that allows controlling for specific country characteristics linked to the level of development and, in

[5] The full description of the components of the intellectual section of the Property Right Index and their sources are available on the website of the parent organization Property Rights Alliance: http://www.internationalpropertyrightsindex.org/methodology.

[6] The large number of questions contained in the BEEPS naturally leads to high non-response rates across variables. Furthermore, information from the CMS provides limited sectoral coverage. We hence restrict our analysis to those firms in the manufacturing sector for which information about the key variables of the study across all sources is available (R&D, distance to the technological frontier, importance of different appropriation mechanisms). Missing observations for control variables have been substituted with arbitrary values and controlled with a dummy for missing observations, to include as many observations.

particular, to the quality of the intellectual property system. The largest countries in the sample, Turkey and Russia, have most firms reporting R&D, whereas Slovenia has the highest incidence – more than 75% of firms report R&D.[7] More than 50% of surveyed companies in Serbia and Belarus, countries with weak if nonexistent IP protection according to the measure used in the study, report investments in R&D.

<< TABLE 1 HERE >>

Table 2 shows the sectors in the sample and the distribution of firms performing R&D for all the countries included in the study. Most firms are in the "Food and Beverages" sector, which represents around 42% of the sample. Economic activities related to metallurgy are also well represented in the sample – around 18% of firms deal with metallic production. Firms in Chemicals and Electronics are the most likely to engage in R&D; in fact, almost half of the surveyed firms in such sectors report having invested in R&D. Table 2 also reports the extent to which the sectors taken into account rely upon different appropriation mechanisms in the US, a market which is expected to provide the strongest IP protection and where we expect companies to choose optimally the extent of legal protection for their products.

<< TABLE 2 HERE >>

In our analysis we also control for other determinants that can explain the likelihood of engaging in RD. Firm size is measured with a set of three dummies, each indicating whether firms are small (SIZE_SMALL, less than 20 employees), 31.74% of the firms in the analysis; medium (SIZE_MEDIUM, between 20 and 99 employees), 35.43% of firms; and large firms (SIZE_LARGE, more than 100 employees), 32.83%. Large companies, the reference group, are expected to be more likely to engage in R&D as they can more easily internalize the spillovers from current R&D projects. Similarly, we control for the number of products the company actually has. Large firms can better internalize spillovers because they can use results from R&D projects on several product lines (Henderson and Cockburn, 1996). As most of our companies have only one product line, we use a dummy variable (MONO_PROD) which takes on value 1 when it falls in the latter case. Firms operating in international markets are definitely more

[7] In fact, according to the data released by the Statistical Office of the Republic of Slovenia (http://www.stat.si/eng/novica_prikazi.aspx?id=3521), in 2009 total gross domestic expenditure on R&D (GERD) accounted for 1.86% of Slovenian GDP. Noticeably, the highest share of GERD was contributed by companies, which represented 58% of total sources of funding R&D.

exposed to competition than companies which only serve local markets and hence more prone to devote resources to stay competitive. Most of the companies in our sample only serve the national market (55.46%) and 62.23% sell up to 90% of their sales nationally. So we measure it with a dummy (EXPORT) which takes on value 1 when firms sell less than 90% of their sales nationally.[8] Around 44% of firms have only one product line, whereas almost 33% sell at least 10% of their products abroad. Whether incumbents or young firms are more likely to engage in R&D is still an open question in the literature. We thus include YOUNG, which equals 1 when a firm is 10 years old or less. We also control for the presence of foreign investors. Foreign-owned firms can be expected to have access to technology and know-how from headquarters (Girma and Görg, 2007). The variable FOREIGN takes value 1 when foreign investors have 51% of shares in the focal company, a share which secures control and hence should enable foreign investors to transfer technologies and know-how to perform R&D. 11% of firms in the sample are foreign-owned for more than 50% of their shares. Foreign firms are more efficient as they are more likely to be standing above the median of the distance from the technological frontier, 12% versus 9% below the median.

We also include 10 dummies to control for industry-wide opportunities, 4 year dummies to control for the year of the interview and 6 dummies to group countries – Central Europe (included Poland, Czech Republic, Slovakia, Slovenia and Hungary), Balkans (Serbia, FYROM (Macedonia), Montenegro, Croatia, Bulgaria, Romania, Bosnia Herzegovina), Baltic (Estonia, Latvia, Lithuania), Eastern Europe (Commonwealth of Independent States, Ukraine and Georgia) and Turkey. Finally, for the sampled firms, 13% did not report their share of sales from the main product line, 3% did not report either the number of full time employees or part-time workers; 6 firms did not report any piece of information regarding the geographical distribution of their sales.

<< TABLE 3 HERE >>

[8] The results do not change when we set the threshold at different values such as 50, 80, 100.

4. Results

We follow the view that institutional characteristics matter in the decision of a firm to invest in R&D in order to introduce innovations. This enables us to analyze how, by interacting with a firm's position along the technological frontier the strength of the IPRs influences a firm's decision to engage in formal R&D. Implicit in this analysis is that firms can substitute internal R&D with spillovers from outside, i.e. by imitating more efficient firms. Equation 1 is the empirical representation of this hypothesis. We first employ a Probit model to estimate the likelihood of engaging in R&D as function of the actual distance of firm *i* to the relevant technological frontier, the functioning of the IPRs system of the country *j* in which the firm operates, their interaction, a set of controls *X*, and a conventional estimating error εi. The probability function of spending in R&D is expressed as follows: $\boldsymbol{Pr(RD_i=1) = f\ (DIST_i;\ IPR_j\ ;\ DIST_i{*}IPR_j\ ;\ X_i;\ \varepsilon_i).}$

In this setting, endogeneity is a concern, especially between the likelihood of investing in R&D and the distance to the frontier. Indeed, firms might be closer to the technological frontier because they invested in R&D, which shows high persistency over time across firms. Table 3 has already indicated that the relationship between DIST and RD is statistically positive. To the purpose, we tried an instrumental approach and extensively looked for (two) instruments which are exogenous, not correlated with ε_i, and relevant, strongly correlated with our measure of distance from the technological frontier.[9] No instrument satisfied the exogeneity requirements. We hence take the results presented below as partial correlations and we will interpret them accordingly.

a. RD, Distance from the frontier and IPRs

Table 4 presents the results of the Logit estimations of equation (1). The key variables of this study – distance to the frontier and strength of the IPRs system - are first estimated one by one with the controls – column 1 and 2 – then together - column 3 - and finally interacted in column 4. Column 5 presents the same estimates as in column 4 with a Linear Probability model. Standard errors have been corrected for outliers and clustered by firm to control for the few observations which have been surveyed multiple times. Year, industry and country group

[9] Mean of the distance values – excluding the focal firm – for each country, year, industry; number of firms considered in the survey for each country, year, industry.

dummies are included in every specification, although they are not reported for brevity. Controls for missing controlling variables are also not reported and are never significant at conventional statistical levels.

<< TABLE 4 HERE>>

The results are in line with the theoretical expectations. Firms closer to the technological frontier are more likely to embark in R&D: stronger IP protection is associated to a higher propensity to invest in corporate R&D. Opportunities in the proximity of the frontier tend to exhaust as the room for imitation is limited and firms need to invest themselves in R&D. The coefficient of the distance to the frontier variable is positive and statistically significant at 1% statistical level. Furthermore, the more confident is the management of a firm that the outcomes of the R&D process will be protected by the current legal system and successfully enforced in case of infringement, the more likely it will be to invest in R&D. The IPRs index used in this study shows a positive and significant coefficient at 5% statistical level when introduced alone and 1% when coupled with the measure of distance to the technological frontier.

The most interesting finding however is the interaction of the latter variables. As this is the outcome of a nonlinear model, it cannot be interpreted as in the case of conventional linear models (Ai and Northon, 2003). Figures 1 and 2 present respectively a visual representation of the semi-elasticities of DIST and IPR for different values of the interaction variable, that is a relative change in the likelihood of investing in R&D given an absolute change in the independent variable at its average, given all other variables at the mean and the interaction variable at the value reported on the horizontal axis.

<< FIGURE 1>>

Figure 1 presents the semi-elasticities for changes in the distance to the frontier at different values of IPR. The dashed line – the value of the semi-elasticity – is positive for low to moderate values of IPR and then it is no longer significant. The decreasing pattern suggests that as the IPRs system provides firms with more control over the ideas generated from innovative activities, firms find proportionally less profitable to invest in R&D themselves as they approach the frontier. In the most extreme case, the likelihood of investing in R&D of a firm which moves from having a productivity of 1/8 of the average US firm in the sector (the average of DIST) to a productivity level of 1/5 (an increase by 0.1 in DIST), will increase by 12% in the case of

Belarus (or Uzbekistan, Kyrgyz and Tajikistan) where no official IPR legislation is present, whereas this will have no meaningful impacts in the case of firms located in the Central European countries where the IPR Index scores above 6.

The results on Figure 2 are more difficult to decipher. The interacted effect of the IPR system is non-significant along most of the technological frontier at 5% confidence level, whereas it is negative and significant at 10% confidence level for firms whose productivity is 0.7 or higher of the frontier. The average semi-elasticity of IPR however is positive although non-significant at the average of DISTANCE. This implies that most of the supposed effects of the IPRs system on the likelihood of performing R&D are subordinated to the actual position of firms along the frontier. IPRs play only a minor role for firms at the proximity of the technological frontier, where opportunities have been exhausted and competition is supposedly fiercer, whereas IPRs induce firms to engage directly in R&D even when room for external opportunities would induce them to do otherwise.

<< FIGURE 2>>

b. Importance of IPRs as appropriability mechanism

Table 5 replicates the results of the Logit estimations of equation (1) by splitting the sample according to the reliance of sectors on patents as effective mechanism to appropriate returns from investments in R&D. As mentioned above, we used the responses by R&D labs in the US reported in the Carnegie Mellon Survey (Cohen et al., 2000) to identify those sectors that consider patents as an effective means for appropriating returns on innovation. The first four columns include firms in those sectors where survey respondents indicated that on average 33% or more of their products are effectively protected by patents. The sectors are Chemicals (ISIC 24), Metal Products (ISIC 28) and Machinery Equipment (ISIC 29). [10]

<< TABLE 5 HERE>>

The results in Table 5 are in line with the expectations. Whereas the incentives to invest in R&D along the distance to the technological frontier are consistent between the two samples, the degree of enforcement of IPRs across country has significant explanatory power in the decision to undertake R&D investment only among firms in sectors for which patent protection

[10] The average share of products for which patents were considered effective across sectors is 31, the median is 33.

is deemed effective, with the exception of those in which foreign investors hold a majority stake (negative and significant coefficient of the FOREIGN variable). Firms in sectors which mostly rely on alternative methods do not seem to be responsive to changes in IP enforcement in their decision to invest in R&D. Thus, the outcomes of Table 4 seem to be driven mostly by those firms which rely sensibly on legal mechanisms – patents in this case given the focus on firms in the manufacturing sector.

<< FIGURE 3 HERE>>

Figure 3 summarizes graphically the effects presented in Table 5. The dashed line indicates the semi-elasticities of IPR for firms in sectors which rely proportionally more on formal mechanisms to appropriate returns from innovation at the 5th, 10th, 25th, 50th, 75th, 95th and 99th centile of the distribution of DIST. The continuous line instead indicates the semi-elasticity of IPR for firms in all other sectors. The latter is never significantly different from zero at conventional statistical levels, whereas the former converges to zero for firms above the median productivity (0.046) and it becomes negative for the top 5% of most productive firms (remember that 3.6% of our firms are actually at the frontier, showing the same if not higher productivity of the average US firm in the same sector in the same year).

c. Innovators

The arguments advanced so far in this paper rest on the assumption that firms have to decide whether to invest in R&D in order to innovate. The decision is the most critical for firms which are closer to the technological frontier because gains from imitations exhaust, whereas firms lagging behind should find it easier to introduce innovations without engaging in R&D. Ideally, we would like to know the importance of imitation for introducing new products and processes; unfortunately, we do not have such piece of information. We instead restrain the analysis to those firms which have introduced a new or upgraded product to the market to see whether there exists substantial heterogeneity with respect to innovators which invest in R&D along the technological frontier and across different degrees of IPR strength.

<< TABLE 6 HERE>>

Table 6 reports the results for the sample of innovative firms, which we define as those firms which have introduced either a new (column 2 of Table 6) or an upgraded (column 3 of

Table 6) product. We make this distinction in order to introduce an element of complexity in the type of innovative activity which is carried on at the focal firm, where new products are expected to request more internal inputs and hence R&D. The first column of Table 6 instead reports the results for both types of firms. The results confirm the intuition advanced in the paper: firms which stand far from the technological frontier are more likely to introduce innovations without engaging in R&D when they operate in countries with weak IPRs systems. Conversely, innovative firms standing far from the technological frontier are more likely to engage directly in R&D when they operate in a country with strong IPRs.[11] A numerical example will illustrate this point: our model predicts that, among the innovators, the likelihood to invest in R&D is 39.18% for firms which are at the 10th of the distribution of DIST (whose relative labor productivity is 0.5% of the respective US average) in countries which do not offer any protection for IPRs. On the opposite, the effect is 47.38% for similar firms in the country with the most developed IP system (Poland in our sample). On the opposite, when we approach the technological frontier (90th percentile of the distribution of DIST, 1/3 of the US average productivity), the predicted likelihood of performing R&D is 47.09% for firms in Poland whereas it is 59.13% for firms where IPR is zero (Belarus for instance). The effect is more pronounced for those firms introducing upgraded products only as compared to the introduction of new products: firms introducing upgraded products in countries with weaker IPRs are less likely to engage in R&D when standing far from the technological frontier, innovating *incrementally*.

d. Age and Size

The relationship between IPRs and R&D along the technological frontier is expected to vary also according to the age and size of the firms. Young and small firms indeed face liabilities related to their age and size, such as limited access to finance and lack of complementary assets to appropriate the returns from their innovations, which should limit their ability to invest in R&D. IPRs should help young and small firms overcome these liabilities as they provide legal protection against imitation and a “bargaining chip” for raising external funds. This effect should in turn be more pronounced for those firms standing away from the technological frontier, where the risk of imitation and the market failures associated to it are more pronounced. Table 7 reports

[11] In general, when foreign investors have 51% or more of shares in the focal company firms are found to be less likely to invest in R&D (negative an d(slightly) significant coefficient of the FOREIGN variable).

the empirical results for the split analysis: Young (10 years or less) vs Old Firms and Small (less than 100 employees) vs Large Firms.

<< TABLE 7 HERE >>

The results confirm that the heterogeneity with respect to IPRs along the technological frontier is driven by small and young firms.[12] The relationship between distance from the frontier and R&D indeed is mediated by the strength of IPRs only for young and small firms, whereas old and large firms are as likely to engage in R&D irrespective of the strength of IPRs and the distance from the technological frontier. Despite being only partial correlations, the results suggest that a functioning IPRs system enables a new class of innovators, mostly young and small, to enter the market place and invest in R&D.

5. Conclusions

In this work we have presented some suggestive evidence on the heterogeneous impact of efficient Intellectual Property Rights on the incentives to embark in R&D. Our empirical strategy is grounded at the cross-road between current advancements in the literature on the institutional determinants of economic growth – in particular the Intellectual Property Rights system and its functioning – and the endogenous growth literature. We have used detailed pieces of information from a comprehensive survey administered to companies in Central and Eastern Europe, countries which came out of planned organizations of economic activities at the same time but which followed different paths of development in the last 20 years and hence show a substantial variability with respect to strength and characteristics of IPRs systems.

Our results confirm the intuitive implications derived from the literature: firms closer to the technological frontier are more likely to engage in formal R&D activities and stronger IPRs systems, protecting the returns from R&D activities from imitation, are effective in promoting investments in R&D. The interesting outcome lies at the intersection of these two dimensions. When the strength of the IPRs system is interacted with the distance to the technological frontier, its effect is no longer significant, ceteris paribus. When we look at its semi-elasticity along the

[12] Small firms controlled by foreign investors are in general less likely to invest in R&D (negative and significant coefficient of the FOREIGN variable).

technological frontier, it emerges that a weak yet positive result is observed for very inefficient firms – the likelihood of engaging in R&D increases by 4.6% (it is expected to be almost 37%), whereas it turns negative and weakly significant as firms are at the technological frontier. Interestingly, when opportunities are largely available – far from the technological frontier – and the uncertainty associated with R&D investments is expected to be lower, effective IPRs induce firms to invest in R&D, possibly by reducing the availability of external opportunity and forcing firms to seek themselves more efficient solutions.

Exploring sectoral differences in the relationship between R&D, IPRs and distance to the frontier, our findings suggest that the observed results are mostly driven by those sectors which rely sensibly on formal mechanisms to protect inventions. Firms in these sectors react positively by investing in R&D to the strengthening of the IPRs system, whereas sectors for which other mechanisms are disproportionally more effective do not. Furthermore, young and small firms seem to be the most likely to engage in R&D when they stand far from the technological frontier under functioning IPRs systems.

These results suggest that the functioning of a sound IPRs system is associated with investments in R&D from a wider range of economic actors: not only the large and established national champions but also *laggard* firms engage in risky investments. Indeed, IPRs seem to be associated with the rise of a new class of innovators, made of young and small firms. Furthermore, strong IPRs are associated to large shares of R&D investors in sectors which are more prone to rely on R&D as appropriation mechanism, suggesting that strong IPRs might influence the direction of technical change in favor of those sectors which make use of legal protection to guarantee innovative returns (Moser, 2005).

At the current stage, we cannot give these results a causal interpretation. In fact, we do not have exogenous variation in labor productivity, our measure of distance to the frontier. This entails that labor distance to the frontier is likely to be strongly influenced by R&D, with a consequent simultaneity problem due to the error term affecting both response and explanatory variable. However, in spite of this possible reverse causality problem, one cannot deny that our results show how a firm’s propensity to engage in R&D is related to the functioning of IPRs systems at different stages of development, at different firms’ demographics and in different industrial settings.

TABLE 1: Distribution of RD performing firms across countries

Country	% RD	# RD	% NO RD	# NO RD	# Firms	IPR*
Albania	0.429	18	0.571	24	42	3.4
Armenia	0.265	68	0.735	189	257	2.7
Azerbaijan	0.105	10	0.895	85	95	3.3
Belarus	0.553	42	0.447	34	76	0
Bosnia	0.540	47	0.460	40	87	3.5
Bulgaria	0.447	42	0.553	52	94	5.6
Croatia	0.526	40	0.474	36	76	4.8
Czech Republic	0.540	67	0.460	57	124	6.8
Estonia	0.522	36	0.478	33	69	6
FYROM (Macedonia)	0.475	38	0.525	42	80	4
Georgia	0.297	35	0.703	83	118	2.3
Hungary	0.295	76	0.705	182	258	6.9
Kazakhstan	0.194	55	0.806	228	283	3.1
Kyrgyz	0.302	29	0.698	67	96	0
Latvia	0.373	25	0.627	42	67	4.8
Lithuania	0.593	54	0.407	37	91	5.9
Moldova	0.414	65	0.586	92	157	2.5
Montenegro	0.263	5	0.737	14	19	3.7
Poland	0.375	133	0.625	222	355	6.6
Romania	0.288	72	0.712	178	250	5.4
Russia	0.521	261	0.479	240	501	4.8
Serbia	0.569	78	0.431	59	137	3.3
Slovakia	0.474	37	0.526	41	78	6.6
Slovenia	0.759	110	0.241	35	145	5.7
Tajikistan	0.357	46	0.643	83	129	0
Turkey	0.310	176	0.690	392	568	5.2
Ukraine	0.452	157	0.548	190	347	4.2
Uzbekistan	0.287	43	0.713	107	150	0
Total	0.393	1865	0.607	2884	4,749	

TABLE 2: Distribution of RD performing firms across industries

NACE	Industry	# RD	% RD	# NO RD	% NO RD	# Firms	Patents*
15	Food	879	0.440	1,121	0.561	2,000	18.26
17	Textiles	94	0.276	247	0.724	341	20
23	Coke, Petrol & Fuel	3	0.750	1	0.250	4	33.33
24	Chemicals	162	0.497	164	0.503	326	40.46
25	Plastics & Rubber	64	0.362	113	0.638	177	32.71
26	Non metallic mineral products	98	0.298	231	0.702	329	25.44
27	Basic metals	36	0.419	50	0.581	86	21.25
28	Fabricate metal products	215	0.280	553	0.720	768	39.43
29	Machinery and Equipment	259	0.430	344	0.570	603	42.94
31&32	Electronics	55	0.478	60	0.522	115	29.89
	TOTAL	1,865	0.393	2,884	0.607	4,749	

* Share of products for which patent protection was judged an effective appropriation mechanism. Extracted from the Carnegie Mellon Survey on Innovation and Appropriability as reported in Cohen et al. (2000)

TABLE 3: Summary Statistics

VARIABLES	ALL		IPR<5		IPR>5		Difference	BELOW MEDIAN		ABOVE MEDIAN		Difference
RD	4749	0,39	2717	0,39	2032	0,4		2374	0,37	2375	0,42	***
DISTANCE	4749	0,12	2717	0,05	2032	0,22	***					
IPRs	4749	4,31						2374	3,29	2375	5,34	***
SMALL	4749	0,32	2717	0,3	2032	0,34	***	2374	0,33	2375	0,31	*
MEDIUM	4749	0,35	2717	0,37	2032	0,34	**	2374	0,37	2375	0,34	**
LARGE	4749	0,33	2717	0,34	2032	0,32		2374	0,31	2375	0,35	***
YOUNG	4749	0,39	2717	0,46	2032	0,3	***	2374	0,45	2375	0,33	***
MONO_PROD	4749	0,44	2717	0,42	2032	0,45	**	2374	0,44	2375	0,43	
EXPORT	4749	0,33	2717	0,26	2032	0,42	***	2374	0,23	2375	0,43	***
FOREIGN	4749	0,11	2717	0,11	2032	0,1		2374	0,09	2375	0,12	***
NO_EXPORT	4749	0	2717	0	2032	0	*	2374	0	2375	0	
NO_PROD	4749	0,13	2717	0,15	2032	0,11	***	2374	0,17	2375	0,1	***
NO_FOR	4749	0,01	2717	0,02	2032	0	***	2374	0,02	2375	0	***
NO_AGE	4749	0,01	2717	0,02	2032	0	***	2374	0,01	2375	0,01	**
CSI	4749	0,47	2717	0,81	2032	0	***	2374	0,75	2375	0,18	***
CENTRAL EUR	4749	0,2	2717	0	2032	0,47	***	2374	0,01	2375	0,39	***
BALKAN	4749	0,17	2717	0,16	2032	0,17		2374	0,15	2375	0,18	**
BALTIC	4749	0,05	2717	0,03	2032	0,08	***	2374	0,02	2375	0,08	***

*, ** and *** indicate 10%, 5% and 1% statistical significance of a t-test on the means of the two samples, assuming different sample size and unequal variance.

TABLE 4: Estimation Results: Coefficients

	1	2	3	4
DISTANCE	0.6703***		0.6688***	2.8256**
	(0.2079)		(0.2078)	-11.258
IPR		0.0795***	0.0794***	0.0928***
		(0.0305)	(0.0306)	(0.0313)
IPR*DISTANCE				-0.3862**
				(0.1929)
MONO_PROD	-0.3679***	-0.3666***	-0.3654***	-0.3689***
	(0.0770)	(0.0770)	(0.0771)	(0.0771)
SMALL	-1.3966***	-1.3925***	-1.3876***	-1.3946***
	(0.1020)	(0.1022)	(0.1022)	(0.1024)
MEDIUM	-0.7931***	-0.7758***	-0.7823***	-0.7879***
	(0.0862)	(0.0864)	(0.0864)	(0.0867)
EXPORT	0.4053***	0.4448***	0.4234***	0.4166***
	(0.0854)	(0.0854)	(0.0858)	(0.0857)
YOUNG	-0.1040	-0.1067	-0.1083	-0.1055
	(0.0801)	(0.0800)	(0.0802)	(0.0802)
FOREIGN	-0.1837	-0.1381	-0.1757	-0.1698
	(0.1195)	(0.1195)	(0.1201)	(0.1199)
CONS	-0.0618	-0.5247	-0.6779	-0.7743
	(0.8205)	(0.8639)	(0.8600)	(0.8583)
N	4749	4749	4749	4749
N_clust	4468	4468	4468	4468
LL	-2.46e+03	-2.46e+03	-2.45e+03	-2.45e+03
CHI_2	8.968.898	8.946.735	9.011.057	8.989.234
PSEUDO R2	0.2282	0.2275	0.2292	0.2302

*, **, *** indicate respectively 10%, 5% and 1% significant level. Standard errors are clustered by firms. Regressions include dummies for year, industry and group of countries. Dummies for missing controlling variables – NO_PROD, NO_AGE, NO_EXPORT; NO_FOR – are also included.

TABLE 5: Estimation Results – Split Sample: Coefficients

	Appropriability: Patents				Appropriability: Other Means			
	1	2	3	4	5	6	7	8
DISTANCE	0.7560**		0.7826**	4.8914**	0.5618**		0.5602**	2
	(0.3293)		(0.3306)	-20.977	(0.2695)		(0.2694)	(10.955)
IPR		0.1091**	0.1145**	0.1413**		0.0115	0.0092	0.0164
		(0.0549)	(0.0551)	(0.0574)		(0.0389)	(0.0389)	(0.0395)
IPR*DISTANCE				-0.7188**				-0.2093
				(0.3476)				(0.1931)
MONO_PROD	-0.2270*	-0.2171*	-0.2208*	-0.2243*	-0.4476***	-0.4502***	-0.4477***	-0.4498***
	(0.1207)	(0.1210)	(0.1210)	(0.1208)	(0.1032)	(0.1031)	(0.1032)	(0.1033)
SMALL	-1.4368***	-1.4389***	-1.4456***	-1.4604***	-1.3442***	-1.3513***	-1.3424***	-1.3469***
	(0.1570)	(0.1570)	(0.1573)	(0.1586)	(0.1362)	(0.1366)	(0.1365)	(0.1367)
MEDIUM	-0.7813***	-0.7564***	-0.7728***	-0.7847***	-0.7940***	-0.7913***	-0.7927***	-0.7956***
	(0.1403)	(0.1402)	(0.1405)	(0.1411)	(0.1118)	(0.1121)	(0.1120)	(0.1121)
EXPORT	0.4661***	0.4950***	0.4751***	0.4628***	0.4004***	0.4234***	0.4029***	0.3988***
	(0.1316)	(0.1314)	(0.1319)	(0.1322)	(0.1156)	(0.1157)	(0.1163)	(0.1162)
YOUNG	-0.1581	-0.1817	-0.1745	-0.1708	-0.0707	-0.0653	-0.0708	-0.0686
	(0.1225)	(0.1223)	(0.1227)	(0.1231)	(0.1073)	(0.1071)	(0.1074)	(0.1073)
FOREIGN	-0.5383***	-0.4554**	-0.5008***	-0.4937**	0.0717	0.1018	0.0712	0.0747
	(0.1906)	(0.1900)	(0.1914)	(0.1922)	(0.1552)	(0.1546)	(0.1555)	(0.1553)
CONS	0.2182	-0.3246	-0.5122	-0.7613	-0.0384	-0.0115	-0.1127	-0.1563
	(0.3438)	(0.4796)	(0.4880)	(0.5070)	(0.8483)	(0.9044)	(0.9045)	(0.9034)
N	1699	1699	1699	1699	3048	3048	3048	3048
N_clust	1622	1622	1622	1622	2896	2896	2896	2896
LL	-984.3889	-985.1063	-982.0323	-978.3535	-1.44e+03	-1.45e+03	-1.44e+03	-1.44e+03
CHI_2	253.0906	250.6678	255.4275	256.8893	693.2072	690.9160	695.0003	693.3913
PSEUDO R2	0.1249	0.1243	0.1270	0.1303	0.2965	0.2955	0.2965	0.2968

*, **, *** indicate respectively 10%, 5% and 1% significant level. Standard errors are clustered by firms. Regressions include dummies for year, industry and group of countries. Dummies for missing controlling variables – NO_PROD, NO_AGE, NO_EXPORT; NO_FOR – are also included.

TABLE 6: Estimation Results: Innovative Sample: Coefficients

	All Innovators	New Products	Upgraded Product
	1	2	3
DISTANCE	3.0895***	2.4094*	3.9975***
	-11.755	-13.998	-11.749
IPR	0.0774**	0.0991***	0.0881**
	(0.0334)	(0.0384)	(0.0350)
IPR*DISTANCE	-0.4528**	-0.3503	-0.5932***
	(0.2002)	(0.2381)	(0.2000)
MONO_PROD	-0.3117***	-0.2110**	-0.3516***
	(0.0850)	(0.1006)	(0.0876)
SMALL	-1.2424***	-1.1839***	-1.2068***
	(0.1105)	(0.1270)	(0.1137)
MEDIUM	-0.7836***	-0.7753***	-0.7667***
	(0.0935)	(0.1089)	(0.0966)
EXPORT	0.4531***	0.4437***	0.4590***
	(0.0931)	(0.1086)	(0.0966)
YOUNG	-0.1093	-0.0572	-0.1247
	(0.0880)	(0.1015)	(0.0918)
FOREIGN	-0.2509*	-0.2843*	-0.2922**
	(0.1296)	(0.1533)	(0.1342)
CONS	-0.6356	-0.4440	-0.5777
	(0.8733)	(0.9023)	(0.8759)
N	3700	2664	34.13
N_clust	3507	2552	3242
LL	-2.01e+03	-1.48e+03	-1.87e+03
CHI_2	693.3189	463.9904	646.2581
PSEUDO R2	0.2106	0.1987	0.2057

*, **, *** indicate respectively 10%, 5% and 1% significant level. Standard errors are clustered by firms. Regressions include dummies for year, industry and group of countries. Dummies for missing controlling variables – NO_PROD, NO_AGE, NO_EXPORT; NO_FOR – are also included.

TABLE 7: Estimation Results: Young and SMes: Coefficients

	YOUNG	OLD	SMEs	LARGE
	1	2	3	4
DISTANCE	4.8505***	2.0183*	3.5940***	1.6846
	(1.6798)	-(1.839)	(1.1237)	(1.4599)
IPR	0.1286**	0.0577	0.1603***	0.0416
	(0.0508)	(0.0404)	(0.0434)	(0.0463)
IPR*DISTANCE	-0.7785***	-0.2259	-0.5074***	-0.2265
	(0.2871)	(0.2041)	(0.1946)	(0.2521)
MONO_PROD	-0.4167***	-0.3328***	-0.4320***	-0.3556***
	(0.1326)	(0.0954)	(0.0987)	(0.1307)
SMALL	-1.3319***	-1.4956***	-0.5834***	
	(0.1817)	(0.1296)	(0.0973)	
MEDIUM	-0.7837***	-0.7948***		
	(0.1666)	(0.1028)		
EXPORT	0.4285***	0.4175***	0.5354***	0.2737**
	(0.1623)	(0.1016)	(0.1140)	(0.1311)
YOUNG			0.0184	-0.2187
			(0.0987)	(0.1447)
FOREIGN	-0.2988	-0.1951	-0.5025**	-0.0955
	(0.2002)	(0.1625)	(0.1995)	(0.1667)
CONS	-0.1280	-10516	-0.8766*	-0.3020
	(1.1124)	(1.0913)	(0.4514)	(13059
N	1842	2906	3187	1558
N_clust	1792	2775	3009	1476
LL	-8589352	-1.58e+03	-1.52e+03	-8731974
CHI_2	4270712	5236309	5635940	2328954
PSEUDO R2	0.2961	0.1954	0.2201	0.1766

*, **, *** indicate respectively 10%, 5% and 1% significant level. Standard errors are clustered by firms. Regressions include dummies for year, industry and group of countries. Dummies for missing controlling variables – NO_PROD, NO_AGE, NO_EXPORT; NO_FOR – are also included.

FIGURE 1: Semi-elasticity (ey/dx) of DIST at different values of IPR. Confidence band at 95%.

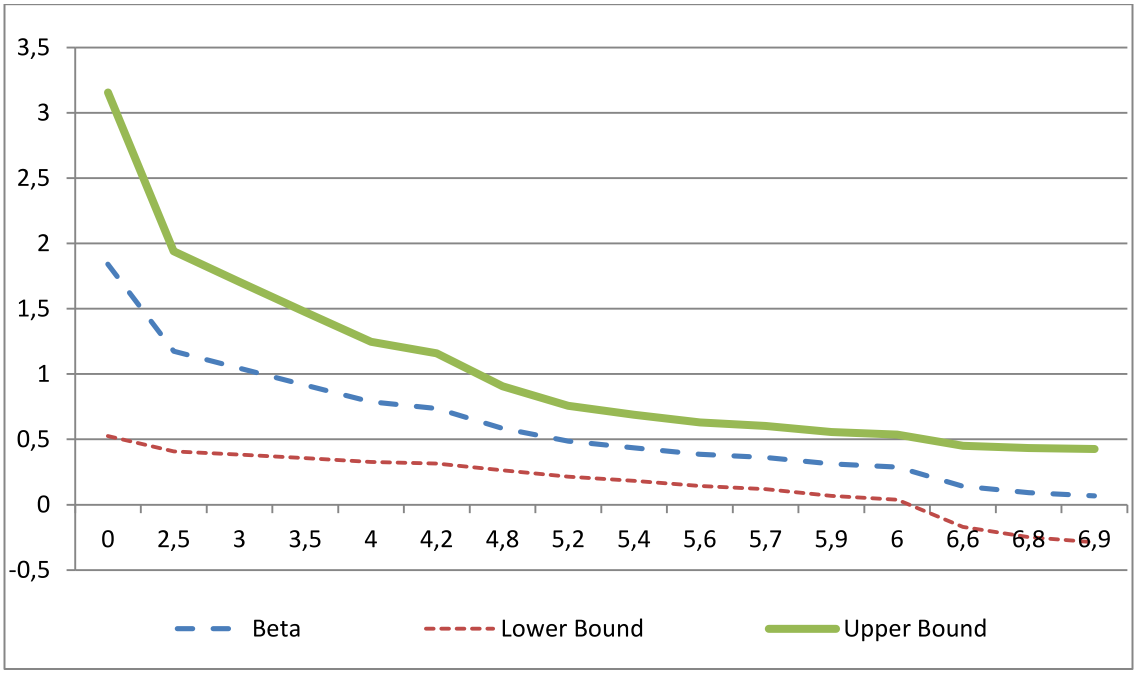


FIGURE 2: Semi-elasticity (ey/dx) of IPR at different values of DIST. Confidence band at 95%.

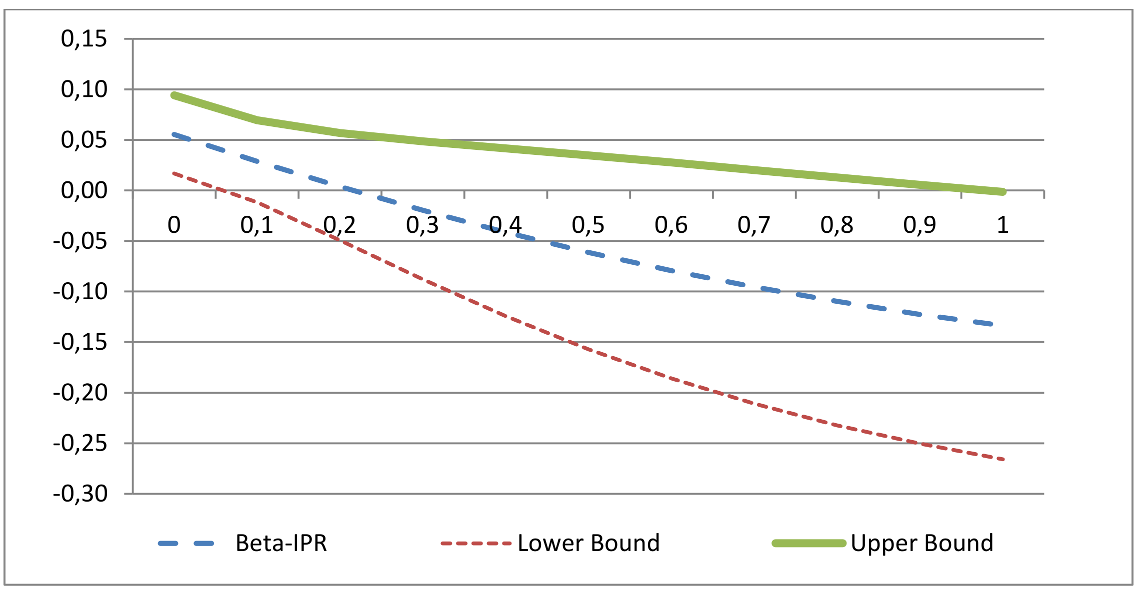
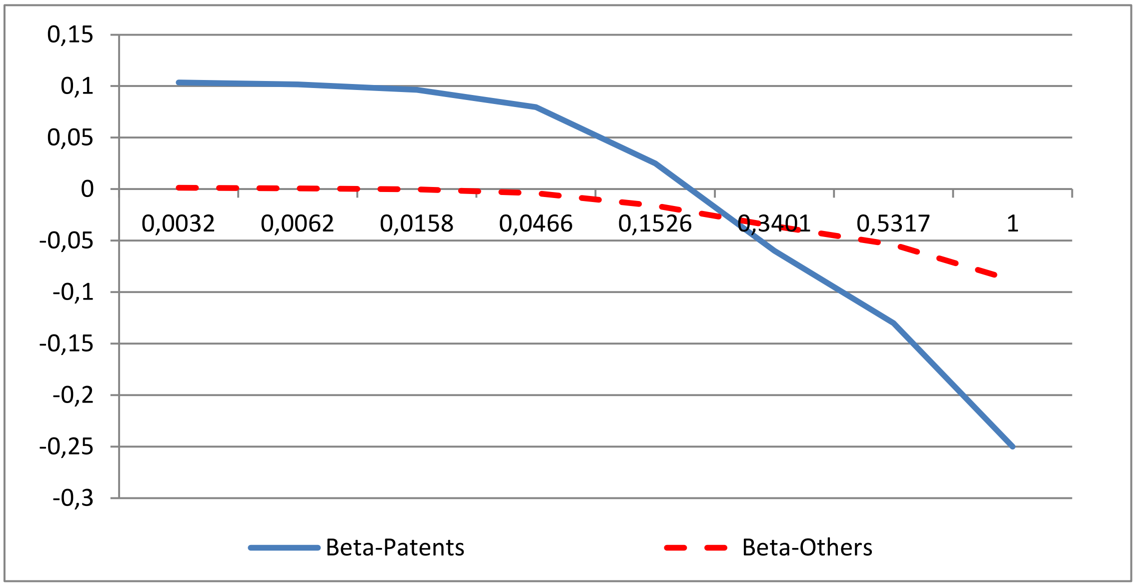


FIGURE 3: Semi-elasticity (ey/dx) of IPR at different values of DIST – Split sample



The continuous line traces the effects of IPR for the sample of firms which rely proportionately more upon patents as mechanism to appropriate returns form innovation whereas the dashed line plots the effect of IPR for the rest of firms.

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